IN THE US PATENT AND TRADEMARK OFFICE

Application No.: **10/006,378**
Filing date: **12/10/2001**
First Named Inventor: **L. W. Wu**
Application Title: **A Nano Powder Production System**
Examiner: **Mayekar, Kishor** Art Unit: **1753**

Mailed June 1, 2004

Amendment

Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

This is a response to the Office Action Summary, mailed 03/10/2004. We would like to request the Office to please reconsider your position of claim rejections for the following reasons:

(1) The Office has cited one of our commonly owned patents (Liu, et al. US 6,398,125, June 4, 2002) as a basis for rejection of Claim 1 and its dependent claims. We would like to point out that Pat.'125 is fundamentally different and patently distinct from the subject patent application in the following ways:

(A) Pat. '125 provides a two-stage process that involves, as a first stage, using a pair of wires and a working gas to form a plasma arc to produce fine-sized **"liquid droplets"** and, as a second stage, using a stream of high-speed gas molecules to strike and **"atomize"** these fine liquid droplets to further break-up the metal liquid droplets to become nanometer-sized. By contrast, the subject patent provides a system that does **not** require the use of an atomizing gas to produce nanometer-sized particles. Instead, the present system operates in such a way that the plasma arc provides sufficient heat (typically in the temperature range of 6,000°C to 20,000°C) to **vaporize** majority (if not all) of the material at the leading tips of the two wires. The vaporized species are naturally at the atomic, molecular, or nanometer-scaled.

(B) Pat. '125 provides a process and apparatus for producing nanometer powders from **metals**. Liu, et al. did not suggest that the twin-wire arc device was applicable to the production of nano-sized metal compounds or ceramics. By contrast, we have found that this arc-induced vaporization system is useful for producing nanometer-sized powder particles from metal, metal alloy, metal compound, and ceramic materials.

(2) The Office indicated that Claims 1, 4, and 6-14 are rejected as being unpatentable over Parker, et al. (US5,514,349) in view of Araya, et al (US4,610,718). We would like to point out that our subject application is a major improvement or innovation that is **not** an obvious extension of Parker's work and the subject application patently differ from Parker's and Araya's patents in the following ways:

(A) The system used in this Parker's process includes a chamber, a non-consumable cathode shielded against chemical reaction by a working gas, a consumable anode vaporizable by an arc formed between the cathode and the anode, and a nozzle for injecting at least one

of a quench and a reaction gas in the boundaries of the arc. This system has several drawbacks. Firstly, the configuration of having a non-consumable electrode and a consumable electrode being paired up to form an arc does not provide efficient vaporization of the consumable electrode. Second, the configuration does not permit an efficient use of the thermal energy with most of the energy being wasted. For instance, the non-consumable electrode must be constantly cooled by using a cooling water flowing around the non-consumable electrode, implying that a significant amount of the energy is carried away by water. Third, since the ionic or plasma arc environment is highly erosive to the non-consumable electrode, this presumably non-consumable electrode actually is gradually eroded away. Consequently, the operator has to replace the electrode periodically from a vacuum chamber and this is a tedious procedure and requires shutting down the whole system. Fourth, the material vaporized from this eroded electrode gets incorporated into the powder particle stream and becomes a contaminant to the final product. By contrast, the two wires used in the subject application determine the chemical composition of the final product. There will be no impurity or contaminant in the produced nano particles.

Furthermore, although Parker, et al did suggest injection of a quench/reactive gas into the chamber, they did not recognize the importance of injecting a reactive gas into a precise location with respect to the arc. By injecting a quench/reactive gas directly into the heart of the arc, one tends to diminish the arc or make the arc unstable. By contrast, we have found that it is very advantageous to inject the reactive gas slightly outside the heart of the arc and, most preferably, downstream from the arc itself (as indicated in claim 1 of the subject application). We have further observed that the vapor species can react with a reactive gas (e.g., oxygen) in a self-sustaining fashion since the reaction heat (oxidation heat) released *in situ* naturally helps to heat and vaporize the metal compound or ceramic clusters generated. Compounds and ceramics (e.g., oxides and carbides) have much higher melting and vaporization temperatures as compared to their pure metal counterparts.

(B) (B-1) Although Araya, et al. did mention, in passing, the potential use of two wires as electrode materials, no evidence existed in US4,610,718 to prove that actual work was conducted on using a twin-wire arc to produce nano-sized particles. It is not a trivial task to maintain a stable arc between two moving wires while the wire tips are being consumed and vaporized away. (B-2) It may also be noted that the powder particles produced by Araya, et al were "ultra-fine" (typically ~0.1 μm and more typically ~ 1 μm). The powders produced by us are typically of 20-40 nanometers. They are truly nanometer particles. (B-3) Araya, et al did not recognize that the use of a twin-wire system can significantly increase the powder production rate. As shown in FIG.4, Table 1 and Table 2 of US4,610,718, Arara, et al could only achieve a powder production rate of up to 50 grams/hour (more typically several grams per hour). In contrast, we have been able to achieve powder production rates typically in the range of 300 to 3,000 grams/hour, a three (3) orders of magnitude improvement. (B-4) Araya et al did not use a reactive gas to produce ceramic or metal compound particles.

(3) The Office has cited Lemelson (US5,628,881) as a basis for rejection of claim 2. It may be noted that Lemelson merely proposed ways to construct multiple plasma arcs for the purpose of

dissociating water molecules into hydrogen and oxygen atoms. Neither Araya, et al. nor Parker, et al. recognized that, in some cases (e.g., high vaporization temperature materials such as W and Ta), a second plasma arc (in addition to the twin-wire arc) could be used to fully vaporize the material. The practice of using a second plasma arc zone was done after a considerable amount of research effort had led to the observation that some high vaporization temperature materials tended to be incompletely vaporized by the twin-wire arc when a high wire-feeding rate was used (in order to push for an ultra-high production rate). One must, therefore, conclude that this innovation is non-obvious and has produced surprising and useful results after considerable R&D efforts.

(4) Although Zurecki, et al (US5,294,242) did provide mechanical and automatic means for feeding wires, the proposed process, just like that developed by Liu, et al., involved "atomizing" the wire melt produced by the arc. This process is fundamentally different from the subject patent, as explained earlier in Paragraph (1).

Please let us know should you require any additional information from us. Thank you.

Respectfully yours,

L. W. Wu Wen-Chiang. Huang

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